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IRRIGATION OF ALFALFA IN IMPERIAL VALLEY

BY

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IRRIGATION OF ALFALFA IN IMPERIAL VALLEY

By WALTER E. PACKARD

ALFALFA IRRIGATION[1]

Recent investigations have indicated certain desirable changes in the methods of irrigating alfalfa in Imperial Valley, which, if carried out will tend to increase yields. At present the annual yields vary from two and one-half to ten tons per acre (besides winter pasturage); four and one-half tons being a fair average for the whole valley. The wide variation is due to the great difference in the character of the soils and to the fact that some fields are irrigated more efficiently than others. Alkali is a factor in the low productiveness in some cases, but taking the valley as a whole, "alkali" is not the main cause for low yields. Although it is certain that the "softer" or sandier types of soil are better adapted to alfalfa than the "harder" or heavier types, experiments have shown that careful irrigation will, in a large measure, eliminate the differences between yields obtained on these types. The number of cuttings and the yields secured from an established stand of alfalfa depend almost entirely upon the efficiency of irrigation.

PREPARING LAND FOR IRRIGATION

A field which is to be planted to alfalfa should be especially well prepared. Any neglect in proper leveling will often cause much trouble and some loss during the entire time that the crop occupies the land, while carelessness in forming the seed bed may result in a thin stand, with the resultant introduction of Bermuda grass. The actual loss in crop area is often considerable (from 5 to 15 per cent) while the slow growth of the alfalfa on high places in the field not receiving sufficient water, represents an unnecessary financial loss to the farmer.

[1] Based in part on work done in coöperation with the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture and the State Department of Engineering of California. The measurements of water applied to alfalfa fields and the field studies of its distribution in the soil and in part the examination of water-logged lands were made by F. J. Veihmeyer, Assistant Irrigation Engineer, Office of Public Roads and Rural Engineering.

Land which has never been plowed should be turned to a depth of from four to six inches, while land which has been plowed will be benefited by a deeper working. If the land is moist, discing should follow the plowing each day in order to prevent the ground surface from becoming too lumpy. The borders should be rebuilt and straightened. A thorough irrigation will indicate any irregularities in the surface which may have been overlooked. After the land is well leveled and irrigated, discing and harrowing will prepare the surface for seeding.

Seeding.—Alfalfa can be satisfactorily broadcasted or seeded with a drill. Experiments have so far indicated that drilling is the preferable practice, if the seed is not planted too deeply (not deeper than one-half inch in heavy soils, or one and one-half inches in light soil). Some remove the seed tubes from behind the drill discs in order to prevent this deep seeding, especially where the land is to be irrigated immediately after planting.

October is considered the best month for planting, although alfalfa can be successfully sown at almost any time between October 1 and April 15. The heavy content of silt in the irrigation water during periods in the fall is the greatest objection to fall planting, while the heavy winds often cause much trouble in the spring.

Irrigation at the Time of Seeding.—Irrigation of the young alfalfa is a particular operation. The soil should be well wetted by a thorough irrigation before planting. Where the seed is drilled in and not irrigated, the fields should be ''planked'' or dragged in order to compact the earth about the seed to insure germination. No irrigation should be given until the plants develop from three to four true leaves. Where the seed is irrigated, which is the custom in Imperial Valley, the first irrigation after planting should be followed by a second light irrigation in from three to five days. The silt carried by the irrigation water often forms an almost impenetrable crust soon after irrigation and with the harder types of soil the surface itself becomes so hard and dry for a quarter of an inch or more that the young plants cannot come through. The second irrigation recommended tends to overcome this hardening and drying and usually insures a good stand. It is important, however, that this second irrigation should come before the plants appear above the ground, on account of the fact that irrigation of the young plants with muddy water before the third or fourth true leaf appears will usually injure the seedlings, in many cases killing so large a percentage as to seriously deplete the stand. Withholding the water from the young plants after they are well sprouted will ordinarily not cause a loss,

for though the surface crust may appear very dry, the roots, which attain a penetration of from eight to fifteen inches, as shown in figure 1, within three weeks after seeding, will ordinarily carry the plants through. After the young plants have developed three or four true leaves, irrigation may proceed in the usual way.

Fig. 1.—1–2, Alfalfa Seedlings, first appearance above ground. Too young to irrigate. 3–4, Alfalfa seedlings too young to irrigate safely with silty water, particularly on heavy soils. 5–6, Alfalfa seedlings large enough to be safe from damage from silty water under ordinary conditions.

WATER REQUIRED FOR ALFALFA

Alfalfa requires from 350 to 1000 tons of water to produce one ton of cured hay.[2] The wide variation in water requirement is due to the varying condition of humidity and temperature under which

[2] *The Soil,* by King, the MacMillan Co.; *Principles of Irrigation Practice,* by Widsoe, MacMillan Co.; *The Water Requirement of Plants,* by Briggs and Shantz, Plant Ind. Bull. 284, U. S. D. A.

the plant is grown. The fact that alfalfa grows so readily in the spring and fall with half the number of irrigations required in the hot and dry summer months, illustrates that fact.[3] In this section where the temperatures are so high and the humidity so low, transpiration is probably greater than in most alfalfa-growing sections of this country,[4] and an unusually large amount of water is required. As this report is not a study of the duty of water for alfalfa the question of the amounts used will not be discussed.

Wilting Point—Amount of Water Necessary for Plant Growth

Not only does alfalfa require a large amount of water but the water must be applied in the right quantities in order that the plant may utilize it. It is impossible for any plant to remove all of the water from a soil on account of the adhesion of the water to the small soil particles. The fact that damp sand holds together while dry sand or sand held under water does not, illustrates this drawing power.

This wilting point varies in different soils from 2 per cent of moisure present in the coarse sands to 18 per cent in the finest clay. As the soil on any farm is a combination of distinct types, usually occurring in layers of various thicknesses, although sometimes being a more or less homogeneous mixture, the wilting coefficient of the average soil in the field is usually some combination of the figures given, as indicated by the table accompanying the soil charts, which give the wilting coefficient of the various types of soil found in the fields studied. When it is realized, however, that alfalfa planted on the sandiest types of soil in the valley would not wilt until the moisture reaches the low limit of 2 or 3 per cent, while alfalfa planted in a plat of heavy clay soil would wilt when 18 per cent of moisture is present, it can be seen that the soils found here must receive different treatment in order to get similar results.

Saturation of the Soil not Desirable

Too much water is as undesirable as too little, for plants need air as well as moisture. Too much water usually causes the greater losses, for it necessitates drainage in many cases in addition to the loss of the crop. Although it is impossible to say just what percentage of

[3] Although the greater transpiration during the summer is probably the main cause for reduced growth during that period, the effect of the intense sunlight undoubtedly has a detrimental effect on the summer growth of the alfalfa, as pointed out by William Lawrence Balls in his book entitled *The Cotton Plant in Egypt—Studies in Physiology and Genetics,* MacMillan Co., London, 1912.

[4] No measurements have been made of the transpiration in this section, but from conclusions made by Briggs and Shantz in Plant Ind. Bull. 284, U. S. D. A., it can be assumed that transpiration is very great in this section.

moisture is needed to maintain a maximum growth of alfalfa, it is safe to conclude that the moisture content in the soil must be somewhere above the wilting point and below saturation.

Conditions Suitable for Control of Moisture

As the rainfall in this section averages below four inches per year, the valley soils are dust-dry to a considerable depth before irrigation water is added. The moisture found in the surface soil must, therefore, come either from seepage from canals or from direct irrigation. This allows an almost perfect control of soil moisture by the irrigator

Fig. 2.—Separating alfalfa roots from soil by hand. Roots are later washed, dried and weighed.

and at the same time affords excellent conditions under which to study the problems of moisture penetration.

GENERAL SURVEY OF EXISTING CONDITIONS

A general survey of the moisture condition in the valley soils showed a wide variation in depth of penetration, as might naturally be expected. In the hard and medium hard soils the penetration averaged about three feet, while in many cases water had not penetrated for more than two feet after two or three years of irrigation. In the medium soft soils the condition is usually good, the moisture penetrating to a depth of from ten to fifteen feet, with no excess accumulation in the lower strata. The sandy soils are commonly over-irrigated. In many places with sandy soils water stands from

two to ten feet from the ground surface, especially where the porous sand overlies impervious clay.

Root Development

In connection with this investigation a study was made of root development in different types of soil and under varying water conditions in order to know how the feeding roots responded to irrigation. An area three feet square was selected in an average location on each field studied and the soil removed to the full depth of root penetration, agitated until all soil particles were washed away, leaving a mass of

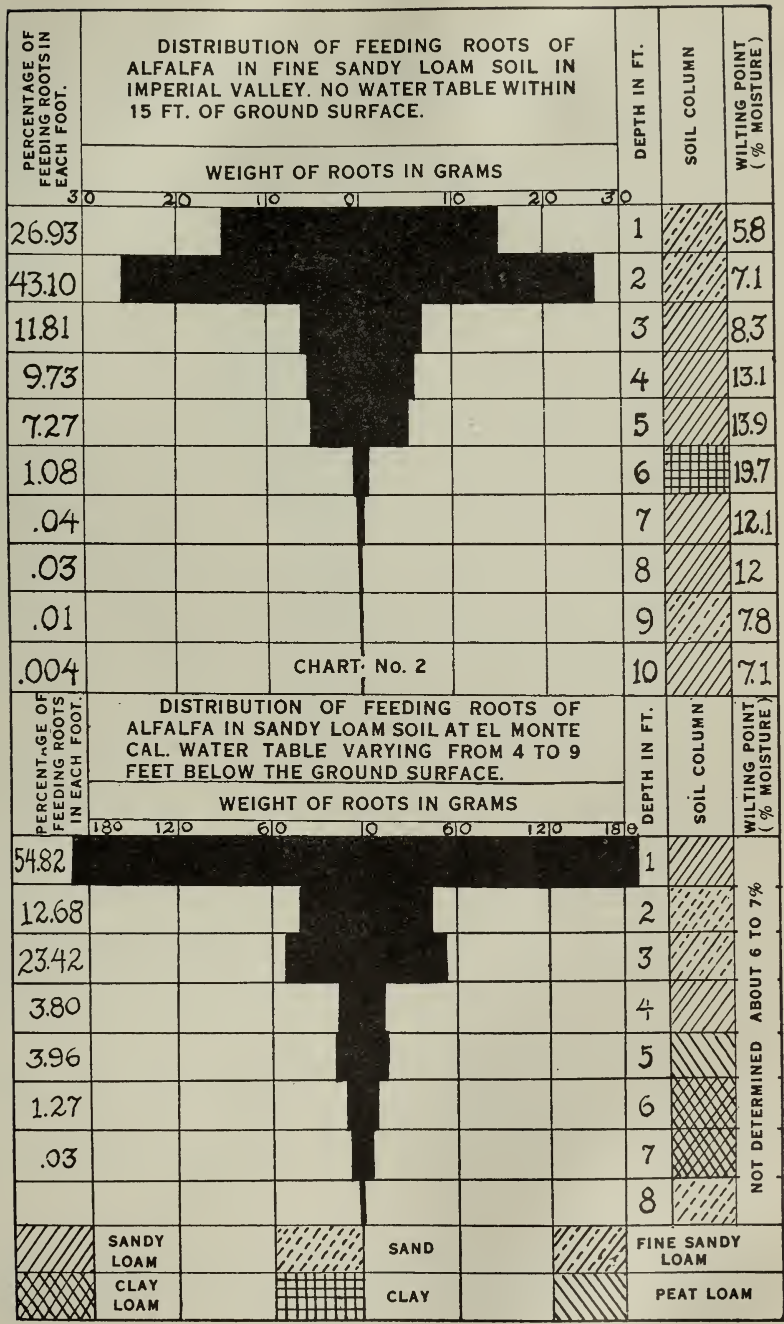
Fig. 3.—Separating soil from roots by placing soil mass in a screen box and agitating in an irrigation ditch.

roots. The roots of various sizes were sorted out and the smallest with a diameter of 1 mm. or less were rewashed, air-dried, and weighed. Charts were made representing the distribution of these roots in each foot to the full depth of root penetration. It is assumed a six-inch layer being removed at a time. The soil was placed in a screen box and the whole held under water in an irrigation ditch and that these small roots represent the feeding roots of the alfalfa and that the charts representing the distribution of these feeding roots really represent graphically the feeding zone of the alfalfa plant.

A Large Proportion of Feeding Roots are in the Surface Soil

The most striking feature brought out by the charts is that from 80 to 90 per cent of the fine roots are found in the upper four feet

CHART No. 1


PERCENTAGE OF FEEDING ROOTS IN EACH FOOT.
DISTRIBUTION OF FEEDING ROOTS OF ALFALFA IN FINE SANDY LOAM SOIL IN IMPERIAL VALLEY. NO WATER TABLE WITHIN 15 FT. OF GROUND SURFACE.
WEIGHT OF ROOTS IN GRAMS
30 20 10 0 10 20 30
DEPTH IN FT.
SOIL COLUMN
WILTING POINT (% MOISTURE)
26.93 1 5.8
43.10 2 7.1
11.81 3 8.3
9.73 4 13.1
7.27 5 13.9
1.08 6 19.7
.04 7 12.1
.03 8 12
.01 9 7.8
.004 10 7.1
CHART No. 2
PERCENTAGE OF FEEDING ROOTS IN EACH FOOT.
DISTRIBUTION OF FEEDING ROOTS OF ALFALFA IN SANDY LOAM SOIL AT EL MONTE CAL. WATER TABLE VARYING FROM 4 TO 9 FEET BELOW THE GROUND SURFACE.
WEIGHT OF ROOTS IN GRAMS
180 120 60 0 60 120 180
DEPTH IN FT.
SOIL COLUMN
WILTING POINT (% MOISTURE)
54.82 1
12.68 2
23.42 3
3.80 4
3.96 5
1.27 6
.03 7
8
NOT DETERMINED ABOUT 6 TO 7%
SANDY LOAM
SAND
FINE SANDY LOAM
CLAY LOAM
CLAY
PEAT LOAM

where the land receives frequent surface irrigations. Deep roots can be formed by a system of deep irrigation, as described in chart No. 3 but under ordinary conditions the largest mass of feeding roots is developed in the top zone. Alfalfa has always been represented as a deep-rooted crop, which it is, but it is very apparent that, under the conditions represented by these charts, a very small percentage of the roots go below five feet. In the type of soil and under the conditions described a majority of the small roots are in the upper two feet, which fact indicates that it is very essential to give this upper zone particular attention in any system of irrigation designed to secure large yields.

Need of Organic Matter Demonstrated

The presence of organic matter has a very noticeable effect on the development of the feeding roots, as indicated by the fact that whenever a stratum containing much organic matter is encountered the feeding roots are always very numerous. A perfect network of these fine roots gathers about a piece of decaying wood or follows down the channels left by roots of native vegetation which formerly occupied the land. The larger roots often pass through a sandy stratum containing little organic matter without sending out very many fine roots until the heavier, richer soil is reached.

This is well illustrated in chart No. 2. The fine roots were very much more numerous in this location than in any Imperial Valley soils studied. The only reasonable explanation of this fact is that the comparatively large amount of organic matter found in the El Monte soils induced this greater root development and in part accounts for the large yields secured on these non-irrigated lands.[5] The number of fine roots in the different soil strata varies with the amount of organic matter present, which accounts for the fact that in the chart more roots are indicated in the third than in the second foot and more in the fifth than in the fourth.

It is very evident that the soils of Imperial Valley need more organic matter, and anything that can be obtained to supply this need should be added whenever possible.

The charts represent so many varied conditions that each will be discussed separately.

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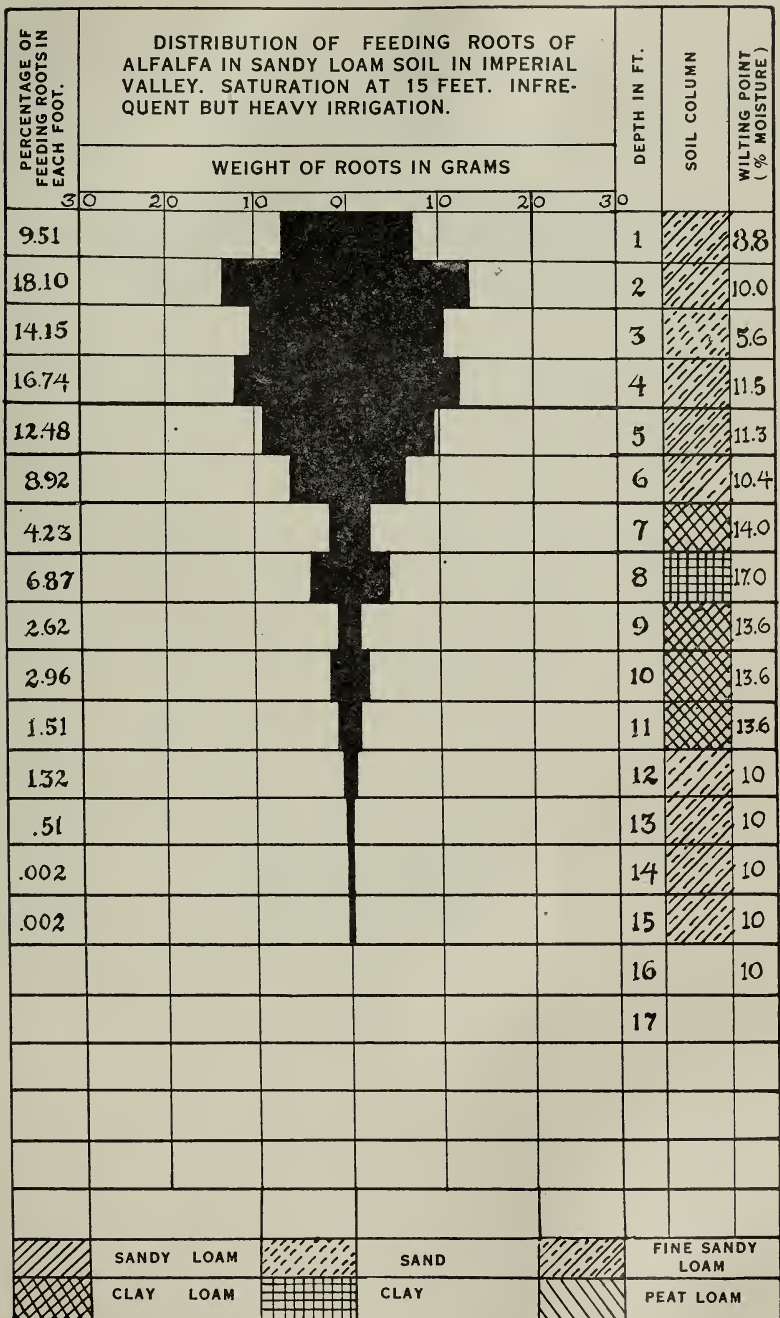
[5] The very large percentage of roots in the surface stratum, as indicated by the chart, is probably too great on account of the fact that it was impossible to separate out all of the organic material other than roots. This may have had an effect on the total quantity in these soils.

CHART No. 3


PERCENTAGE OF FEEDING ROOTS IN EACH FOOT.
DISTRIBUTION OF FEEDING ROOTS OF ALFALFA IN SANDY LOAM SOIL IN IMPERIAL VALLEY. SATURATION AT 15 FEET. INFREQUENT BUT HEAVY IRRIGATION.
WEIGHT OF ROOTS IN GRAMS
30 20 10 0 10 20 30
DEPTH IN FT.
SOIL COLUMN
WILTING POINT (% MOISTURE)
9.51 1 8.8
18.10 2 10.0
14.15 3 5.6
16.74 4 11.5
12.48 5 11.3
8.92 6 10.4
4.23 7 14.0
6.87 8 17.0
2.62 9 13.6
2.96 10 13.6
1.51 11 13.6
1.32 12 10
.51 13 10
.002 14 10
.002 15 10
16 10
17
SANDY LOAM
SAND
FINE SANDY LOAM
CLAY LOAM
CLAY
PEAT LOAM

DISCUSSION OF CONDITIONS REPRESENTED BY THE CHARTS

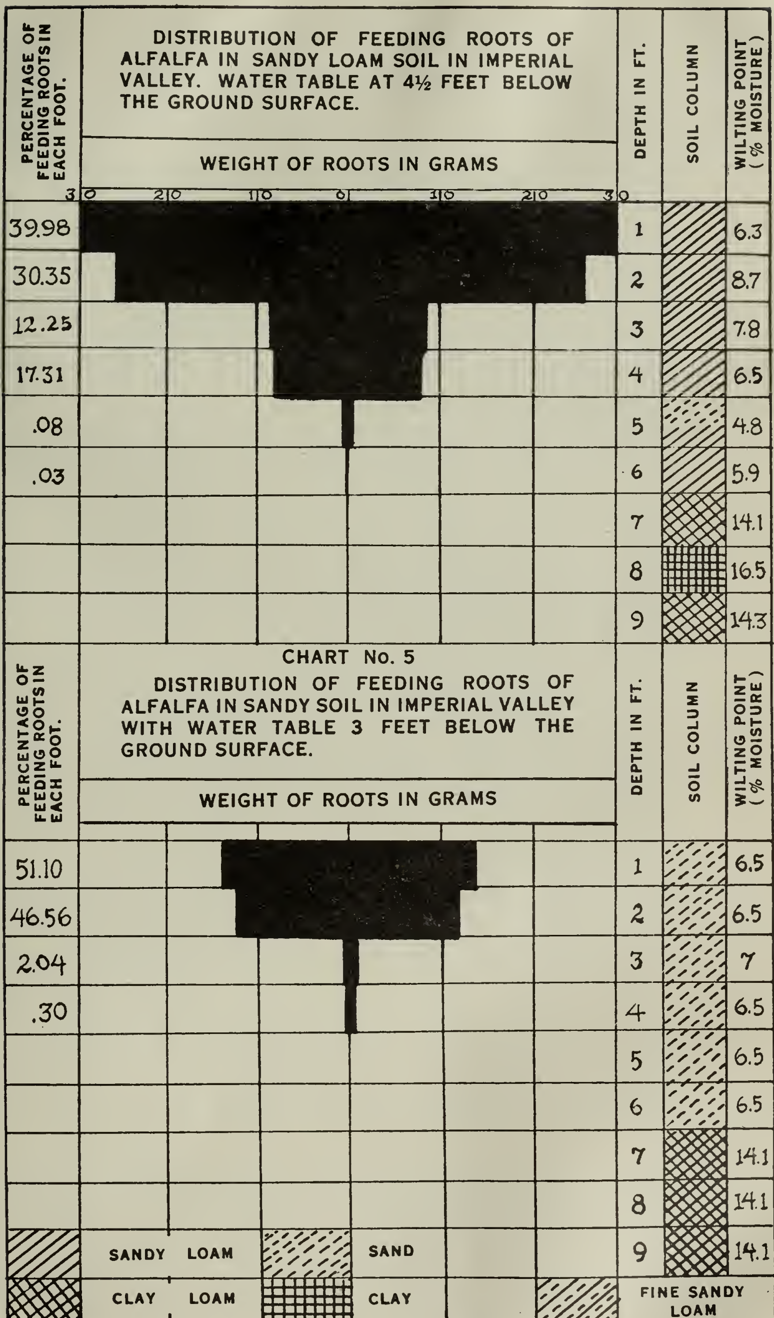
Chart No. 1 represents the weights of feeding roots in each foot in depth in the field giving the highest yield of alfalfa of those studied. The alfalfa was nine years old and produced from six to nine tons per acre besides winter pasture, in an average of six cuttings. The soil is a sandy loam to a depth of five or six feet and from there to twelve feet, clay, clay loam, and sandy loam strata alternate. The greatest number of roots is in the second foot, with 95 per cent in the upper four feet, which is to be expected in a soil where all of the moisture is supplied on the surface by irrigation and none by sub-irrigation.

The moisture in this field had penetrated to a depth of more than fifteen feet. No water table existed at this depth, although the lower strata were very near the saturation point. Water was applied at more frequent intervals than on any of the fields under observation, so that the top foot of soil seldom dried out to below the wilting point, during the period between irrigations. The value of this system of frequent light irrigations is at once apparent for the roots in this field go to a depth of eleven feet, and in all of that area the percent of moisture in the soil between irrigations ranges between saturation and the wilting point, always affording ample moisture for all roots.

It seems apparent therefore that frequent irrigation, sufficiently light to prevent a water-logging of the soil and at the same time sufficient to allow for deep penetration will keep up the moisture supply in the zone of greatest root development and will as a result give the largest yields. One heavy irrigation may add as much water as two light irrigations, but in the one case much of the water will be lost by seeping below the root zone, while in the others the water will be largely retained in the top soil as available moisture for plant growth.

Chart No. 3 represents the deepest-rooted alfalfa studied. The soil is a sandy loam for a depth of six feet where a five to six-foot stratum of clay loam and clay begins. The field produces from five to six tons of alfalfa hay per year besides winter pasture. When this land was leveled a large amount of water was used which undoubtedly saturated the lower soil strata. After the alfalfa stand was about a year old the ranch was sold and no water was applied to this field for about ten months. During this time the alfalfa roots depended upon the moisture already in the soil to maintain plant growth, and as a result the feeding roots were developed in the full depth of twelve

CHART No. 4


PERCENTAGE OF FEEDING ROOTS IN EACH FOOT.
DISTRIBUTION OF FEEDING ROOTS OF ALFALFA IN SANDY LOAM SOIL IN IMPERIAL VALLEY. WATER TABLE AT 4½ FEET BELOW THE GROUND SURFACE.
WEIGHT OF ROOTS IN GRAMS
30 20 10 0 10 20 30
DEPTH IN FT.
SOIL COLUMN
WILTING POINT (% MOISTURE)
39.98
30.35
12.25
17.31
.08
.03
1 2 3 4 5 6 7 8 9
6.3
8.7
7.8
6.5
4.8
5.9
14.1
16.5
14.3
CHART No. 5
DISTRIBUTION OF FEEDING ROOTS OF ALFALFA IN SANDY SOIL IN IMPERIAL VALLEY WITH WATER TABLE 3 FEET BELOW THE GROUND SURFACE.
PERCENTAGE OF FEEDING ROOTS IN EACH FOOT.
WEIGHT OF ROOTS IN GRAMS
DEPTH IN FT.
SOIL COLUMN
WILTING POINT (% MOISTURE)
51.10
46.56
2.04
.30
1 2 3 4 5 6 7 8 9
6.5
6.5
7
6.5
6.5
6.5
14.1
14.1
14.1
SANDY LOAM
SAND
CLAY LOAM
CLAY
FINE SANDY LOAM

feet.[6] During this period the alfalfa did not grow fast, as a majority of the feeding roots of the plant were located in the top soil where there was not sufficient moisture for plant growth, the plant maintaining itself through the roots in the moist strata below.

The condition just described is often found in sections where no irrigation water is applied to the field, but where the roots go down to water, as shown in chart No. 2. This represents the distribution of roots in a sandy soil near the San Gabriel River at El Monte, Los Angeles County, where the alfalfa is not irrigated. The El Monte field was selected to illustrate this, as no alfalfa is grown without irrigation in Imperial Valley. In this field the water table varies from four feet to nine or ten feet below the surface of the ground. In the winter, during the rainy period when the San Gabriel River is high, the water stands at the highest point.

The alfalfa makes the most rapid growth in the spring, as the rain keeps the moisture well above the wilting point at the ground surface and the water table at four feet furnishes, by capillarity, sufficient moisture for maximum plant growth in the top root zone. When the rains stop and the water table lowers, the growth slackens up and during the dry weather when the top soil is relatively dry the alfalfa does not much more than maintain itself. The fine roots which tend to follow the water down keep about even with the water plane and thus secure enough moisture to keep the plant alive and to support some growth during the summer months. In this field the roots were found to a depth of eight feet while water was encountered at nine.

Effect of Water Table on Root Development

Much has been written regarding the dangers of a rise of water table, as large areas of good land have been rendered worthless on that account, but it seems evident from this chart and others that follow, that, where alkali is not a factor, no apparent damage is done until the water table rises above the four-foot mark or thereabouts. The roots are rotted off wherever they are submerged for any length of time,[7] and as soon as the water table rises about four feet, a sufficient number of the roots are killed to affect the plant. If water rises closer

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[6] When the root studies were made the land was dry below eight feet on account of the fact that recent irrigations have not been sufficient to penetrate for more than eight feet. These lower roots, although not dead, were of no value to the plant as they were in dry soil. It is apparent, therefore, that the roots below eight feet were developed during the ten months when the substratum was saturated and no water was applied to the surface of the field.

[7] The period of submergence necessary to kill the roots is not known, except that submergence for a few days will not, but for two or three months will.

than three feet so large a proportion of roots are affected as to greatly reduce the yield by killing all but the more resistant plants. In the field just described the roots below four feet were all of this year's growth, as indicated by the fact that they branched from roots which were rotted off at the four-foot level. The lower strata were full of

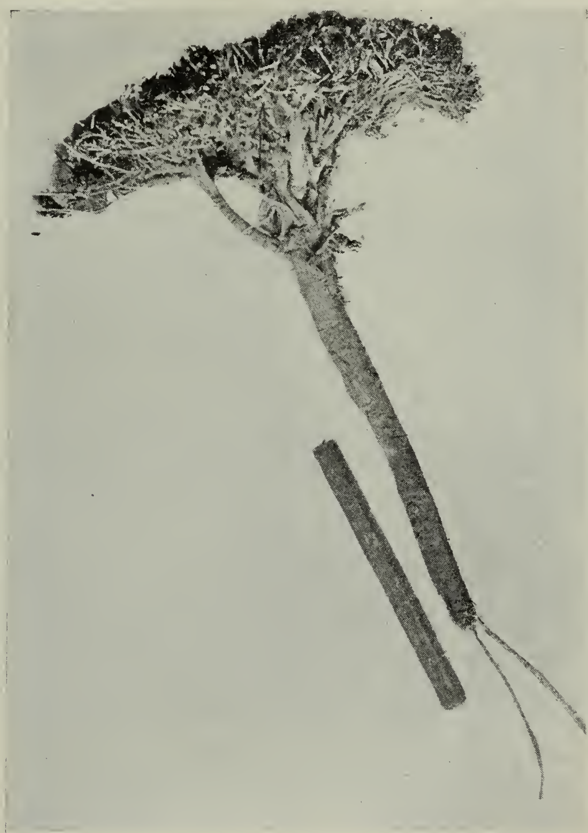

Fig. 4.—Alfalfa root rotted off by rise of water table. Two small roots are shown growing from the main root after water table had lowered.

fine roots of previous years' growth which had died out with the rise of the water table.

The fact that the rise of the water table is not necessarily injurious until it begins to reach an area of large root development near the surface is indicated in charts No. 4 and No. 5. The alfalfa in the field represented by chart No. 4 is growing above a water table varying from four to six feet. As a result all of the feeding roots are in

the top four feet, the greatest number being in the top foot. This field is being damaged by the existence of a high water table, but is still producing good crops. The geld is flooded very heavily and water often stands on the alfalfa several hours before it finally disappears. The roots which had penetrated below four feet before the rise of water table were decayed, but the effect was not serious enough to kill the plants on accoount of the fact that a sufficient quantity of roots existed in the upper four feet to maintain a normal growth.

Fig. 5.—Bermuda grass soon occupies the land when alfalfa has been killed out by excessive flooding or by rise of water table.

In the field represented by chart No. 5, however, the alfalfa is rapidly dying out and Bermuda grass taking its place. The water table in this case is so close to the surface that a large majority of the roots are killed, leaving only the top two feet as a feeding zone.

It seems apparent, therefore, that, so far as the water table is concerned, alfalfa will produce large yields if the water does not come close enough to the surface to rot a large percentage of the roots. The frequent testimony, both from this section and others, that alfalfa does better with a water table at four feet than when no water table exists is probably based on the fact that a water table at that depth tends to maintain a maximum moisture condition in the top soil by

capillarity. If the water table is within three feet of the surface and remains constant, alfalfa will often produce good crops, as it does in part of the San Joaquin Valley where this condition exists, but when the water table fluctuates and sometimes rises above three feet, so large a number of roots are rotted as to greatly reduce, if not entirely kill out the stand. When alkali is present in sufficient quantities in water-logged lands, the salts tend to concentrate on the surface and often become so strong as to kill all vegetation.

Root Development and Moisture Distribution in Clays and Clay Loams

In so-called "hard soils" the feeding roots are necessarily largely on the surface, as the irrigation water often does not penetrate for more than three to four feet. If a large yield of alfalfa is secured on this type of soil it is necessary to keep the moisture content of the top soil above the wilting point by frequent irrigations. It is apparent that if by infrequent irrigation the top foot or two dry out, the roots in that zone are of no use to the plant until further irrigation brings the water in the soil above the wilting point. This condition is very common in the valley and usually accounts for the fact that alfalfa grows slowly and often blossoms when only a foot or so high on the harder types of soil. Frequent irrigation will add the needed moisture to this top soil area, will maintain the moisture above the wilting point, and will allow for a rapid growth of alfalfa.

GENERAL CONCLUSION

In order, then, to get satisfactory yields of alfalfa a large amount of water must be supplied during the season, it must be supplied frequently enough so as to prevent a drying of the surface soil on the one hand and water-logging of the soil on the other. This desirable condition can only be accomplished by conforming the grade of the land, the frequency of irrigation, the size of the field, and the head of water used to the types of soil to be handled. As the soil types vary widely, it will be necessary to consider each general type separately. It will be sufficient for this purpose to divide the soils of the valley into three general classes, sandy or porous soils, sandy loams or medium soft soils, and clay loam and clay or heavy soils.

METHOD OF IRRIGATION RECOMMENDED FOR POROUS SOILS

The great danger in all sandy or porous soils is that too much water will be applied and a high water table thus formed. This condition is already prevalent in some sections, where sand overlays clay.

The clay tends to retard the downward movement of the water, and as a result there is an accumulation of water above this stratum, which gradually rises toward the surface as irrigation continues. This rise of water table can be prevented in a majority of cases by adopting one or all of the following suggestions.

Use smaller lands. The lands or borders for irrigation on this type of soil should usually not exceed one-eighth of a mile in length and, if necessary, not more than twenty-five to thirty feet in width in order that the water applied may reach the lower end without oversaturating the upper end. There are many fields in the valley where water has been run from a quarter to a half mile on these types of soil, with the inevitable effect of adding too much water at the upper portion of the field, which of course results in a rise of water table. The exact length and width of the lands must depend on the condition of the surface and the degree of porosity of the soil. If the soil is very sandy the lands should be both narrow and short in order to allow a quick irrigation.

Use large head. In addition to using smaller lands than are now being used, it would be an advantage in nearly all cases to use much larger heads of water than are at present used on this type of soil. In other parts of California a head of from eight to twelve feet is often run onto one land in order to get quick irrigation. A small head will often disappear so rapidly at the upper end that it takes a very long time to cover the field. The size of head must conform to the size of the land and the character of the soil, the point being to run the water so quickly over the land that an excess above the requirements of the plants will not be added to any part of it. A head of three to eight cubic feet per second for the very sandy soil and from two to four cubic feet per second for the more compact sandy loams would not be too great. A soil auger can be very effectively used in determining the soil moisture condition where one is uncertain regarding the moisture penetration.

In cases where the grade is less than five feet to the mile in the directions in which the lands are built, and it can be increased to a eight to ten feet to the mile by changing the direction of the lands, it should be done. There will be no danger of the soil washing at that grade and it will materially help in getting the water across the land quickly.

It is very important that the recommendations made be followed out in case of light sandy soils for there is always danger of the formation of water table when water penetration is rapid. The depth of the soil should not be considered as a safeguard, as it only takes

time to saturate the large soil reservoir. In 1910 ground water was found at a depth of fifteen feet in a field planted to alfalfa. In two years the level had raised to nine feet, so that water stood within six feet of the surface, and water is now so close to it that alkali is being brought up and deposited on the ground surface by capillary action. Every man owning "soft" land should investigate the condition in his field and conform his irrigation practice to meet the conditions present.

Drainage is Often Necessary in Sandy Soils

In some cases a water table is formed through seepage from canals, particularly when canals are located in sandy territory on a sufficient grade to prevent a deposit of fine silt on the bottom and sides. The rate of seepage is so great under these conditions that the effect of a rise or fall in the water level in a canal can often be noticed a distance of one-eighth of a mile from the canal within twenty-four hours. This condition can only be handled by drainage or by lining the ditches causing the seepage. In most cases the ditches in the valley are on such slight grade that the deposits of silt prevent rapid seepage.

When a ranch is near a deep drain, or one of the river channels, a satisfactory system of drainage can be installed to remove the excess of water which may have accumulated by either seepage or over-irrigation. In many cases such facilities do not exist and the drainage question is a community problem which must be met as such.

A surface drain at the end of a field will be of great value in preventing a scalding of the alfalfa by standing water, although such drains do not affect the ground water condition. There is sometimes a danger of depending too much upon these drains, with the result that the lower ends of the fields are badly flooded, but where properly used much waste can be prevented. "Experience has taught the necessity of considerable depth. This should never be less than six feet—and eight feet would be a better minimum."[8] The outlet drains would have to be still deeper.

METHOD OF IRRIGATION RECOMMENDED FOR MEDIUM SOILS

The sandy loam soils are easily irrigated, although too much or too little water is sometimes applied with the usual results. There is no good excuse, however, for not having a good moisture condition in these medium soft soils. If the alfalfa does not grow as rapidly

[8] "The Drainage of Irrigated Land," by R. A. Hart. Bulletin 190, U. S. Dept. of Agr.

as desired an investigation should be made of the moisture condition in the soil by the use of a soil augur or a spade. If the top soil appears too dry before irrigation it would perhaps be wise to give the field an additional light irrigation between cuttings. If the lower strata are saturated the recommendations given for hard or clay soils should be followed.

METHODS OF IRRIGATION RECOMMENDED FOR COMPACT SOILS

The problem on the hard type of soils is to get the water deep into the soil in sufficient quantities to maintain rapid growth.

In many cases the fact that the surface has been irrigated is taken as evidence that the water has soaked in, while in reality only the top six inches have been wetted. It is very common to find dry soil at a depth of two and one-half to three feet in these heavy soils. In order to get proper penetration the following recommendations should be followed out.

Size of land. Land should be from an eighth to a quarter mile long, very seldom running one-half mile, as is now a common practice. It is difficult to handle water properly on long lands, as a flooding of the lower end can seldom be avoided. On land that is comparatively flat, borders fifty to one hundred feet apart are satisfactory, but when the land is at all steep, lands should be narrowed down to twenty-five to thirty feet wide so that a small head will cover the surface evenly.

Head of water to use. In order to get proper penetration, it is necessary to run a comparatively small head for a long time. Fields which yielded from two and one-half to three tons per acre per year have been made to double the yield through this system of irrigation. A small head of water requires a much longer time to travel over the field than a larger head and allows of a better penetration. Land which could be wetted only to a depth of three feet when large heads were used were successfully wetted to a depth of five and six feet by the use of smaller heads. The effect of smaller heads running for a longer time is more noticeable with furrow irrigation than with flooding, but the effect is marked in both cases.

Grade of land. The grade of hard land should not be over five or six feet to the mile. A grade of four feet is satisfactory if the land is properly leveled.

Drains should be made at the lower ends whenever practicable, as scalding is very common on this type of soil. The drains should be large enough to prevent the accumulation of water at the lower ends.